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(54) **High impedance transponder with improved backscatter modulator for electronic indentification system**

(57) A transponder 20 for an electronic identification system is disclosed and claimed. The transponder is characterized in that it presents a high input impedance (>400Ω) at an input thereof which is directly connected to an antenna 22 with a matched high input impedance. The transponder is aimed at improving the voltage recovered on capacitor C_2 from an interrogation signal and thus the operational range of the system. The modulator 30 of the transponder is arranged to backscatter modulate the interrogation signal at a modulation depth of less than 80%, preferably in the order of 30%. This also results in an improvement of the operational range of the system.

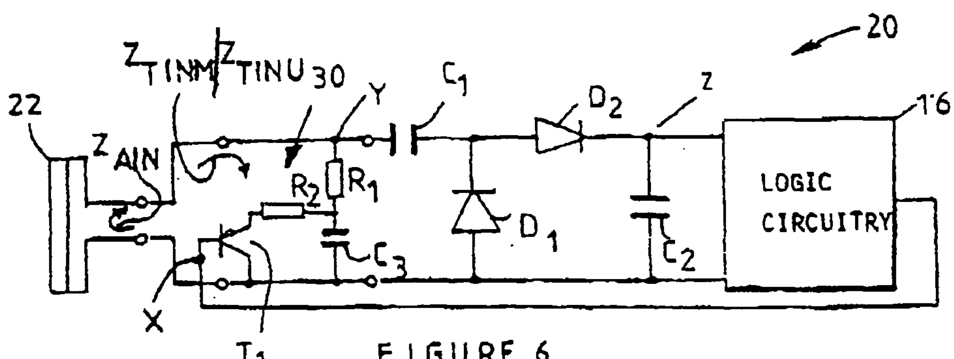

FIGURE 6

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Description

INTRODUCTION AND BACKGROUND

[0001] THIS invention relates to electronic identification systems including an interrogator and a plurality of transponders. The invention more particularly relates to transponders forming part of such a system.

[0002] Known electronic systems of the aforementioned kind include an interrogator including a transmitter for transmitting an interrogation signal to the transponders and a receiver for receiving a response signal from the transponders. A microprocessor in the interrogator identifies a particular transponder from a data stream in the response signal. Each transponder comprises an antenna and a detector circuit for receiving and collecting power from the interrogation signal, to present a high enough voltage on a storage capacitor, to power a modulator and logic circuitry of the transponder, which logic circuitry in turn generates the aforementioned data stream. The data stream is used to modulate the energizing signal at about 100% modulation depth and to reflect back to the interrogator a portion of the energy in the energizing signal, by what is known as backscatter modulation. The antenna of the transponder is normally a single element half wavelength dipole antenna having a feedpoint impedance of 50Ω to 100Ω. This antenna is matched by a suitable impedance matching network to a low input impedance of 125Ω to 200Ω of the detector circuit.

[0003] In the known systems, the effective distance of the backscattered response signal greatly exceeds the distance over which the transponders can be powered by the energizing signal. The inhibiting factor is the voltage required on the capacitor to power the modulator and logic circuitry of the transponder. The voltage recovered and thus the operating range achievable with the known low input impedance transponders, especially those with a small integrated storage capacitor and which modulate the energizing signal at about 100% modulation depth, are not satisfactory.

OBJECT OF THE INVENTION

[0004] Accordingly it is an object of the present invention to provide an alternative transponder with which the applicant believes the aforementioned disadvantages may at least be alleviated.

SUMMARY OF THE INVENTION

[0005] According to the invention there is provided a transponder for an electronic identification system including an input connected to transponder circuitry, the transponder being characterized in that an input impedance at the input thereof is at least 400Ω.

[0006] The transponder according to the invention therefore is aimed at improving retrieved voltage from the interrogation and energizing signal as opposed to the optimizing of retrieved power, as in the prior art transponders.

[0007] The transponder circuitry may include a modulator connected to the input, a signal detector connected to the modulator and logic circuitry for generating an identification code; the input may be connected directly to an antenna without an impedance matching circuit between the antenna and modulator; and a real part of a feedpoint impedance of the antenna is substantially equal to a real part of the input impedance.

[0008] The transponder circuitry may include a voltage multiplier circuit, such as a voltage doubling circuit.

[0009] The transponder circuitry is preferably integrated on a single chip. The integration may be done utilizing CMOS technology.

[0010] The antenna may comprise a multi-element half wavelength dipole. Typically the antenna may comprise a three to five element half wavelength dipole. The antenna may further comprise an inductive reactive element to cancel out a capacitive reactive component in said input impedance at a preferred operating frequency. The inductive reactive element may for example comprise a loop formation provided at or near the feedpoint of the antenna.

[0011] In another embodiment the antenna may comprise a half wavelength dipole wherein the feedpoint is suitably positioned off-centre, so that the feedpoint impedance approximates said input impedance. The antenna may be suitably longer than a half wavelength, to yield an inductive reactive component to cancel out a capacitive reactive component in said input impedance at a preferred operating frequency.

[0012] Further according to the invention the modulator may be configured to modulate an energizing signal received via the antenna with an identification code signal at a modulation depth of less than 80%.

[0013] The identification code signal may include a binary data stream and the modulator may include switching means connected to be controlled by the data stream, to switch an impedance arrangement into and out of the transponder circuitry to change the input impedance between a first value wherein it is substantially matched with the feedpoint impedance of the antenna and a second value wherein it is at most 80% of the first value.

[0014] Also included within the scope of the present invention is a transponder including transponder circuitry including a modulator for modulating a received energizing signal with a response signal at a modulation depth of less than 80%.

[0015] The modulation depth is preferably between 20% and 40%, typically in the order of 30%.

[0016] The response signal may include a binary stream and the modulator may include switching means connected to be controlled by the binary stream, to switch an impedance arrangement into and out of the transponder circuitry to change an input impedance at

an input of the transponder circuitry between a first value wherein it is substantially matched with a feed-point impedance of an antenna connected to the transponder circuitry and a second value wherein it is at most 80% of the first value.

[0017] The switching means may include an active switching device such as a transistor and the impedance arrangement may include a resistor.

[0018] Also included within the scope of the present invention is a transponder for an electronic identification system, the transponder including:

- an antenna connected to an input of transponder circuitry;
- the transponder circuitry including:
  - an energizing signal detector connected to the antenna;
  - a storage capacitor connected to the detector to store a voltage retrieved from the energizing signal;
  - a modulator connected to the antenna; and
  - circuitry for generating a control signal for the modulator;
  - the modulator being arranged in response to the control signal to modulate the energizing signal at a modulation depth of less than 80%.

BRIEF DESCRIPTION OF THE ACCOMPANYING DIAGRAMS

[0019] The invention will now further be described by way of example only, with reference to the accompanying diagrams wherein:

figure 1	is a basic block diagram of a prior art transponder;
figure 2	is a basic block diagram of a transponder according to the invention;
figure 3	is a block diagram of the transponder according to the invention showing the detector circuit including a voltage doubling circuit in more detail;
figure 4	is a diagrammatic representation of an antenna forming part of the transponder according to the invention;
figure 5	is a diagrammatic representation of another antenna which may form part of the transponder according to the invention;
figure 6	is a block diagram of the transponder showing the modulator circuit in more detail; and
figures 7 to 9	are waveforms at various points in the circuit represented by the block diagram in figure 6.

DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

[0020] A block diagram of a prior art transponder 10 is shown in figure 1. The transponder 10 comprises a half wavelength dipole antenna 12 having a feedpoint impedance Z_{AIN} of in the order of 50Ω to 100Ω, typically 73Ω. A matching network 14 is provided between the antenna 12 and detector and modulator circuitry 16, to match the impedance of the antenna to the input impedance Z_{DIN} of the detector and modulator circuitry, which typically is in the order of 125Ω to 200Ω. The detector and modulator are connected to logic circuitry 18. The detector collects power from a received interrogation signal to accumulate a voltage on a storage capacitor, to drive the logic circuitry and modulator circuit. The operational range of an interrogator (not shown) and transponders 10 is dependent on the voltage recovered by the detector circuit and stored on the capacitor.

[0021] The operational range of prior art systems with the aforementioned low impedance antenna (73Ω) and low input impedance detector and modulator circuitry (125Ω - 200Ω), is not satisfactory. Furthermore, the matching network 14 contributes to the cost of the known transponder. Still furthermore, as shown in figure 9, in prior art transponders utilizing 100% modulation, the voltage on the storage capacitor intermittently falls below a minimum value required on the capacitor.

[0022] A block diagram of a transponder 20 according to the invention is shown in figure 2. The transponder 20 comprises a high impedance antenna 22 (Z_{AIN} >400Ω) connected directly to high input impedance transponder circuitry including detector and modulator circuitry 24. The detector and modulator circuitry 24 is connected to the logic circuitry 26.

[0023] By increasing the input impedance Z_{TIN} of the detector and modulator circuitry 24, the recovered voltage is also increased. The relationship is determined by the formula

$$V = \sqrt{P x Z_{TIN}}$$

wherein

P =	the power of the signal; and
Z_{TIN} =	the input impedance of the transponder circuitry.

[0024] Furthermore, the voltage is further increased by providing a voltage multiplier circuit in the form of a voltage doubling circuit 28 (shown in figure 3). The voltage doubling circuit 28 operates as follows.

[0025] During a positive half cycle S_{INP1} of the interrogating signal S_{IN} current flows through capacitor C_1 and diode D_2, to charge storage capacitor C_2, to the peak voltage of the half cycle S_{INP1}. During a negative half cycle S_{INN}, current flows through diode D_1, to reverse charge capacitor C_1, to the peak voltage of the

negative half cycle S_{INN}. During the next positive half cycle S_{INP2}, the voltage on capacitor C_1 is added to the voltage of the positive half cycle S_{INP2} to charge capacitor C_2 to the peak to peak voltage of the signal S_{IN}.

[0026] The input impedance Z_{TIN} is determined by *inter alia* the impedance of stray circuit resistances, inductances and capacitances; the impedance of the rectifier diodes D_1 and D_2 when not conducting; the forward resistance of the diodes D_1 and D_2 when conducting; the impedance presented by the logic circuitry 26; and the impedance of the modulator 30, when in a high impedance state.

[0027] By increasing the impedance Z_{TIN}, the recovered voltage is also increased. The impedance Z_{TIN} may be increased by about one order compared to that of the known detector circuits, to about 1200Ω to 1800Ω by suitably integrating the modulator 30, voltage doubling circuit 28 and logic circuitry 26 on a single chip 32.

[0028] In order to increase the input impedance Z_{TIN}, it is necessary to reduce the effects of capacitive components and resistances in parallel with the input, to reduce the junction capacitance of the diodes D_1 and D_2 and to increase the impedance of the modulator 30. The impedance of the logic circuitry 26 may significantly be increased from 15,000Ω to greater than 300,000Ω by using the latest CMOS technology in the fabrication of the integrated circuit wafer. However, the greatest contributor to the low input impedance (125Ω to 200Ω) of the known transponders is the modulator circuit, which is connected directly across the input. The second contributor is the aforementioned diodes D_1 and D_2

[0029] By raising the input impedance Z_{TIN} of the chip 32, the modulator 30 is not required to pass as high currents as the known modulators. This has the benefit of allowing a smaller modulator active semiconductor device (see T_1 in figure 6), which in turn causes the stray capacitances to be reduced and the resistance to be increased, thereby raising Z_{TIN} still further.

[0030] The input impedance Z_{TIN} can be raised to several thousand ohms by increasing the unsaturated forward resistance of the diodes D_1 and D_2 and ensuring an ideal balance between the storage capacitor C_2 and the coupling capacitor C_1. It has been found that an input impedance Z_{TIN} of in the order of 1200Ω to 1800Ω, would provide good results.

[0031] To assist with matching the antenna 22, the input impedance Z_{TIN} of the chip 32 may deliberately be kept to be capacitive.

[0032] In order to exploit the benefits of the higher transponder input impedance, a high impedance signal source is also required. Instead of using the conventional approach of a low impedance antenna combined with an impedance transforming network 14 to match the chip input impedance as shown in figure 1, this invention uses a high impedance antenna 22 which connects directly to the detector and modulator circuitry 24 on chip 32, without the need for a matching network.

[0033] The antenna 22 may comprise a multi-element half wavelength dipole. The feedpoint impedance Z_{AIN} of such an antenna is given by the equation

$$Z = 73 \times n^2$$

wherein n is the number elements of equal diameter.

[0034] . Thus, a four element dipole antenna will have a feedpoint impedance of about 1170Ω whilst a five element dipole will have a feedpoint impedance of about 1825Ω. By using a multiple wire dipole antenna, the feedpoint impedance Z_{AIN} may be closely matched to the input impedance of the detector Z_{TIN}, without the need for impedance transforming or matching networks.

[0035] A typical five element dipole antenna 22.1 is shown in figure 4 and addition of a hairpin loop 34 connected across the feedpoint 36 is used to provide a pure resistive match at the operating frequency, by introducing suitable inductive reactance of an equal magnitude to the aforementioned capacitive input reactance in Z_{TIN} of the transponder circuitry.

[0036] In figure 5 there is shown another embodiment of a relatively high feed point impedance Z_{AIN} antenna designated 22.2. The antenna 22.2 is a folded half wavelength dipole which is fed off-centre. The impedance Z_{AIN} is given by the centre feedpoint impedance multiplied by the square of the current ratio at the centre of the antenna to the current ratio at the actual feedpoint. By making the antenna slightly longer than half a wavelength, the impedance Z_{AIN} will be inductive, to cancel out the aforementioned capacitive input reactance in Z_{TIN} of the transponder circuitry.

[0037] It is believed that by connecting the antenna 22.2 directly to the chip 32, radiation pattern problems with off-centre fed antennas may be avoided

[0038] It has been found that with a transponder 20 according to the invention the operational range of an identification system may be increased significantly compared to that of conventional systems. The cost of the transponders 20 could also be lower, due to the elimination of the matching network 14.

[0039] In figure 6, the modulator 30 is shown in more detail. The modulator 30 is driven by a data stream (shown in figure 7) generated by logic circuitry 16 and which data stream is characteristic of the transponder. As stated hereinbefore, the modulator and logic circuitry are provided with electrical power by a charge accumulated by the detector and multiplier circuit and stored on storage capacitor C_2. The capacitor C_2 is preferably integrated with the other electronic components on chip 32.

[0040] As also stated hereinbefore, the modulator 30 which is controlled by the aforementioned data stream, modulates the energizing signal received from the interrogator, to reflect some of the energy in the energizing signal back to the interrogator, by what is known as backscatter modulation. The modulation depth is deter-

mined by the ratio of an unmatched input impedance Z_{TINU} of the transponder to a matched input impedance Z_{TINM}.

[0041] The aforementioned modulation depth is obtained by matching the input impedance of the transponder Z_{TINM} when the modulator 30 is off (that is when the data stream is logic high) to the antenna impedance Z_{AIN}, so that maximum energy is available to the detector circuit and by providing a controlled mismatch of the input impedance Z_{TINM} of the transponder when the data stream is logic low, so that only a controlled portion of the energizing energy is reflected or scattered back to the interrogator.

[0042] It has been found by the applicant that a modulation depth of between 20% and 40% provides an acceptable compromise between on the one hand effective signal recovery by the interrogator of the backscattered data stream carrying response signal and on the other hand, adequate collection by the transponder of power from the energizing signal to be stored in the form of a voltage on the capacitor C_2.

[0043] In a first practical example, the antenna impedance is 463 ohm with 11.7nH inductance at 915 MHz parallel thereto. Resistor R_1 and capacitor C_3 are selected such that when the modulator is "off" (that is when the data stream is logic high), Z_{TINM} is 463 Ω with 2.54 pF capacitive reactance at 915 MHz in parallel therewith. When the data stream is low and modulator 30 is "on", transistor T_1 switches R_2 into the transponder circuitry, so that the unmatched impedance Z_{TINU} is 148.9Ω with 2.27 PF capacitive reactance at 915 MHZ parallel thereto. This yields a modulation depth of in the order of 30%.

[0044] In a second practical example, there is used a three-element halfwave dipole antenna with a feedpoint impedance of 680Ω and 19 nH inductance at 915 MHz parallel thereto. Resistor R_1 and capacitor C_3 are selected such that when the modulator 30 is "off", Z_{TINM} is 680Ω in parallel with 1.56 pF at 915 MHz. When the modulator is "on", the unmatched impedance Z_{TINU} is 475Ω with 2.65pF at 915 MHz in parallel therewith. This also yields a modulation depth of in the order of 30%.

[0045] Waveforms at points X, Y and Z in figure 6 are shown in figures 7 to 9, respectively. The waveforms shown in dotted lines are those at corresponding points in circuits of prior art transponders utilizing 100% modulation.

[0046] It will be appreciated that there are many variations in detail on the transponder according to the invention without departing from the scope and spirit of the appended claims.

Claims

1. A transponder for an electronic identification system including an input connected to transponder circuitry, the transponder being characterized in that an input impedance at the input thereof is at least 400Ω.

2. A transponder as claimed in claim 1 wherein the transponder circuitry includes a modulator connected to the input, a signal detector connected to the modulator and logic circuitry for generating an identification code; wherein the input is connected directly to an antenna without an impedance matching circuit between the antenna and modulator; and wherein a real part of a feedpoint impedance of the antenna is substantially equal to a real part of the input impedance.

3. A transponder as claimed in any one of claims 1 and 2 wherein the circuitry includes a voltage multiplier circuit.

4. A transponder as claimed in any one of claims 1 to 3 wherein the circuitry is integrated on a single chip.

5. A transponder as claimed in any one of claims 2 to 4 wherein the antenna is a multi-element dipole antenna.

6. A transponder as claimed in any one of claims 2 to 4 wherein the antenna is an off-centre driven dipole antenna.

7. A transponder as claimed In any one of claims 2 to 6 wherein the modulator modulates an energizing signal received via the antenna with an identification code signal at a modulation depth of less than 80%.

8. A transponder as claimed in claim 7 wherein the identification code signal includes a binary data stream and wherein the modulator includes switching means connected to be controlled by the data stream, to switch an impedance arrangement into and out of the transponder circuitry to change the input impedance between a first value wherein it is substantially matched with the feedpoint impedance of the antenna and a second value wherein it is at most 80% of the first value.

9. A transponder including transponder circuitry including a modulator for modulating a received energizing signal with a response signal at a modulation depth of less than 80%.

10. A transponder as claimed in claim 9 wherein the modulation depth is between 20% and 40%.

11. A transponder as claimed in claim 9 or claim 10 wherein the modulation depth is in the order of 30%.

12. A transponder as claimed in any one of claims 9 to

11 wherein the response signal includes a binary stream and the modulator includes switching means connected to be controlled by the binary stream, to switch an impedance arrangement into and out of the transponder circuitry to change an input impedance at an input of the transponder circuitry between a first value wherein it is substantially matched with a feed-point impedance of an antenna connected to the transponder circuitry and a second value wherein it is at most 80% of the first value.

13. A transponder as claimed in claim 12 wherein the switching means includes an active switching device and the impedance arrangement a resistor.

14. A transponder for an electronic Identification system, the transponder including:

- an antenna connected to an input of transponder circuitry;
- the transponder circuitry including:
  - an energizing signal detector connected to the antenna;
  - a storage capacitor connected to the detector to store a voltage retrieved from the energizing signal;
  - a modulator connected to the antenna; and
  - circuitry for generating a control signal for the modulator;
  - the modulator being arranged in response to the control signal to modulate the energizing signal at a modulation depth of less than 80%.

15. An electronic identification system including

- an interrogator for transmitting an energizing signal;
- a plurality of transponders;
- each transponder including an antenna connected to transponder circuitry;
- the transponder circuitry including:
  - an energizing signal detector connected to the antenna;
  - a storage capacitor connected to the detector to store a voltage retrieved from the energizing signal;
  - a modulator connected to the antenna; and
  - circuitry for generating a control signal for the modulator;
  - the modulator being arranged in response to the control signal to modulate the energizing signal at a modulation depth of less than 80%.

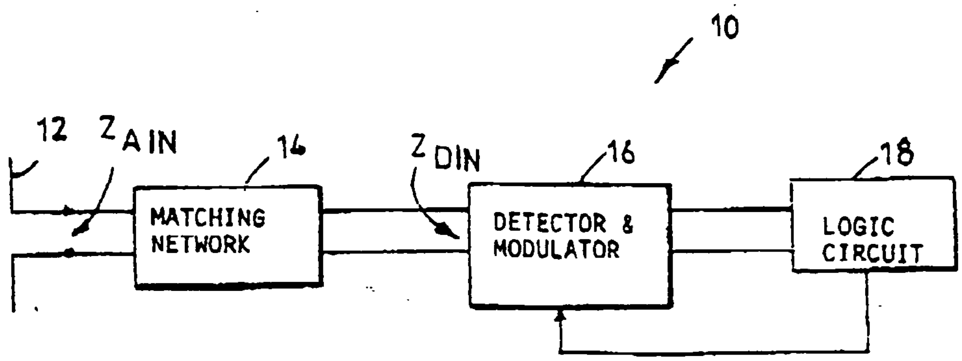

FIGURE 1 (PRIOR ART)

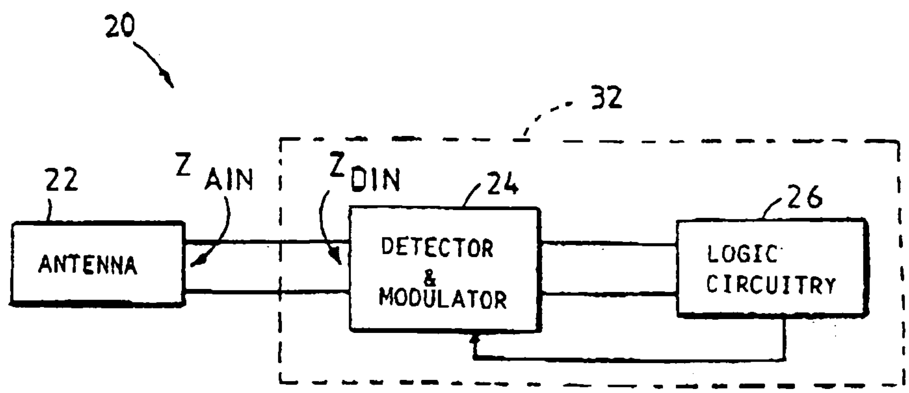

FIGURE 2

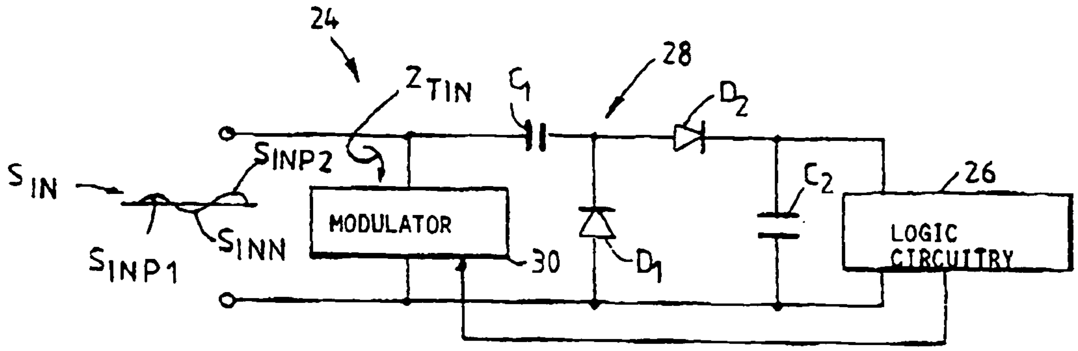

FIGURE 3

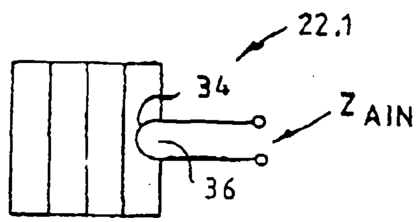

FIGURE 4

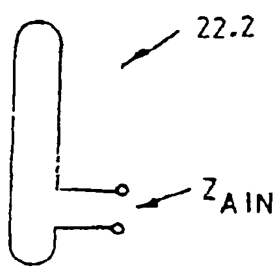

FIGURE 5

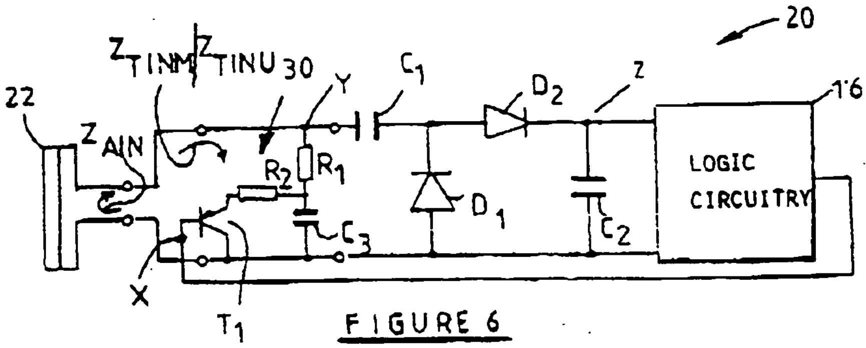

FIGURE 6

FIGURE 7

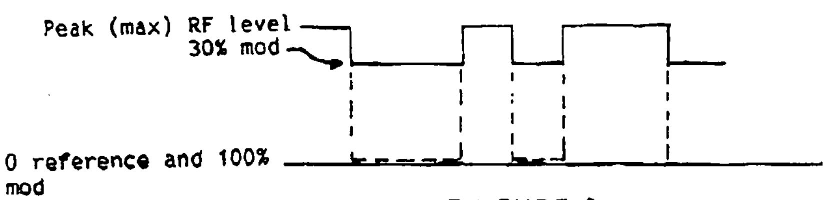

FIGURE 8

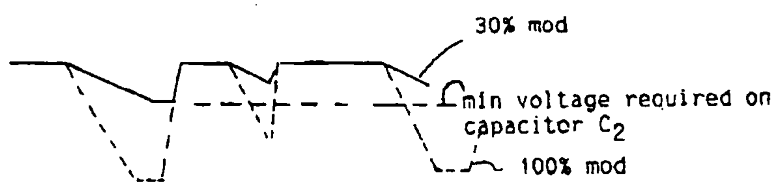

FIGURE 9